

# OpenStax Astronomy, Ch.9: WS Solutions (Apr-2021)

## Solutions

1. What is the composition of the Moon, and how does it compare to the composition of Earth? Of Mercury?

The Moon is principally composed of silicate rocks, whereas Earth has more metals and volatile compounds. Earth has an iron core, but the Moon does not. Earth has liquid water in its surface layer, but the Moon does not. Mercury contains substantially more metals than the Moon, with a significant iron-nickel core.

2. Why does the Moon not have an atmosphere?

The Moon's mass, and therefore its gravitational force, is not large enough to retain gases and volatile compounds. Therefore, any gases released on the Moon quickly escape into space.

3. What are the principal features of the Moon observable with the unaided eye?

The dark maria, the lighter highlands, and a few large craters such as Tycho are visible. The contrast between the light and dark of these features is sometimes called "the man in the Moon."

4. Frozen water exists on the lunar surface primarily in which location? Why?

Frozen water exists primarily in deep craters on the Moon's south pole. Parts of these craters are permanently in shadow and therefore do not receive enough energy from the Sun to evaporate the ice and escape into space.

5. Outline the main events in the Moon's geological history.

After the formation, more than four billion years ago, the low density silicates cooled first and made up the initial crust. This surface was exposed to heavy meteor cratering early in the Moon's history. About 3.8 to 3.3 billion years ago, extensive volcanism released large amounts of lava that flowed over the surface filling in the lowest parts of the large impact basins and forming the darker maria we see today. Both the highlands and the maria continue to be battered by additional impacts ever since.

6. What are the maria composed of? Is this material found elsewhere in the solar system?

The maria are composed chiefly of basalt. Basalts are also found on Earth, Venus, Mars—and to a much lesser extent—Mercury.

7. The mountains on the Moon were formed by what process?

The long, semi-circular mountain ranges that border the maria are debris ejected from the massive impacts that formed these basins, piled up at the edge of the bowl dug out by the explosion that resulted from the impact. The central peak mountains in large craters are due to rebound from the sudden removal of overlying rock.

8. With no wind or water erosion of rocks, what is the mechanism for the creation of the lunar "soil?"

Billions of years of impacts breaking up the rocks and scattering the debris over the surface have created lunar "soil." Enough impacts have occurred to cover much of the surface with sand- and dust-sized particles.



9. Explain the evidence for a period of heavy bombardment on the Moon about 4 billion years ago.

There are about 10 times more craters on the highlands than on a similar area of maria. The radioactive dating of highland samples shows that they are only slightly older than the maria, about 4.2 billion years versus 3.8 billion years. If the impact rate was constant over the Moon's history, the highlands would be least 10 times older than the maria, or about 38 billion years old. That's older than the age of the universe. Thus, the impact rate must not have been constant, and been at a much higher rate earlier than 3.8 billion years ago.

10. What is the main consequence of Mercury's orbit being so highly eccentric?

Mercury's distance from the Sun varies hugely, ranging from 46 million km at perihelion to 70 million km at aphelion.

11. Describe the basic internal structure of Mercury.

Mercury is one of the densest of the planets, at  $5.4 \text{ g/cm}^3$ . It has an enormous iron-nickel core nearly 3500 km in diameter, which is encased in a rocky/silicate crust about 700 km deep. The metallic core, representing nearly 60% of the planet's total mass, produces a weak magnetic field.

12. How was the rotation rate of Mercury determined?

With the use of radar. Radar beams were directed to Mercury and the reflected beams showed the tell-tale signs of Doppler broadening. The measured degree of this frequency broadening provided an exact value for the rotation rate of Mercury.

13. What is the relationship between Mercury's rotational period and orbital period?

Mercury's rotation is 59 Earth-days long, while the year is 88 Earth-days long. That is a ratio of 3 to 2. Thus, three Mercury days equals two Mercury years.

14. The features of Mercury are named in honor of famous people in which fields of endeavor?

Artists, writers, composers, and other contributors to the arts and humanities.

15. Why did it take so long for geologists to recognize that the lunar craters had an impact origin rather than a volcanic one?

There are two main reasons why it was thought a century ago that lunar craters had volcanic origins and not impact origins (as is now believed). Geologists suffered from a rather myopic Earth-dominated view: most craters we see today on Earth have volcanic origins, so they assumed the same for the Moon. Many of the large lunar craters would have had to form by the impact of projectiles many kilometers in diameter, and the presence of such large Earth-crossing asteroids was not known until about forty years ago.

16. How might a crater made by the impact of a comet with the Moon differ from a crater made by the impact of an asteroid?

There would be essentially no difference between a crater made by the impact of a comet versus an asteroid. The shape of any crater is very nearly circular since the crater forms mainly by the explosion of the projectile. The size of the crater depends primarily on the speed of the projectile and to a lesser extent on the mass. Typical comets or asteroids colliding with the Moon would likely have similar speeds and masses. Both comets and asteroids would be vaporized upon impact with the Moon, so it would be almost impossible to find a signature of either one in the crater debris.



The one indication of a comet that might be preserved would be water vapor that could condense in the cold, permanently shadowed regions at the poles.



17. Why are the lunar mountains smoothly rounded rather than having sharp, pointed peaks (as they were almost always depicted in science-fiction illustrations and films before the first lunar landings)?

The primary reason why the lunar mountains are smoothly rounded is that there has been no water/ice erosion on the Moon as there has been on Earth. This type of erosion tends to undercut rocks and produce sharp, pointed peaks.

18. The lunar highlands have about ten times more craters in a given area than do the maria. Does this mean that the highlands are 10 times older? Explain your reasoning.

The number of craters is proportional to the age only if the cratering rate has not varied over time. If the rate were higher in the past (cratering events were more frequent), then less time would be required to accumulate many craters. Since we know from radioactive dating of lunar samples that the Moon is only 4.5 billion years old, whereas the mare lava surfaces are typically 3.5 billion years old, it is not possible that the cratering rates have remained constant. This is the reasoning that leads us to the idea of an early heavy bombardment of the Moon. However, note that this reasoning requires that we have independent ages from lunar samples. Before the Apollo expeditions, some scientists had actually estimated that the highlands were about 10 times older than the maria.

19. At the end of the section on the lunar surface, your authors say that lunar night and day each last about two Earth weeks. After looking over the information in the chapter on the Earth, Moon, and Sky, and this chapter about the motions of the Moon, can you explain why? (It helps to draw a diagram for yourself.)

The Moon's synchronous rotation means that it orbits Earth in the same time that it spins on its axis, in a period of roughly 29 days. To simplify matters, let us assume that during any 29-day period, we can neglect Earth's motion around the Sun. Then the Sun will remain in the same direction as seen from the Moon during such a 29-day period. This means that, as the Moon turns, a point on the Moon will face toward the Sun for half the time and away from the Sun for half the time. Thus, the lunar day and night. The Moon was once closer to Earth than it is now. When it was at half its present distance, how long was its period of revolution? (See Orbits and Gravity for the formula to use.)

At half its present distance, Kepler's third law tells us that the Moon must have had a period shorter by a factor of two to the 3/2 power, or 2.83. Therefore the period was  $27.3 \text{ days} / 2.83 = 9.6 \text{ days}$ .

